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Formulating Urban Design Guidelines for Optimum Carrying Capacity of a Place

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Abstract

"Growth is inevitable and desirable, but destruction of community character is not. The question is not whether your part of the world is going to change. The question is how." -Edward T. McMahon
We live in a world of uncontrolled development and depleting resources. There is growing concern about the consumption of precious resources and various efforts to conserve it. But these efforts are often unproductive. One of the reasons for this is unplanned consumption and development. Architects and urban designers are especially challenged as they are a group of professionals who contribute to such mishaps. There is a need to limit such development. This study aims at estimating such limits by optimizing carrying capacity of a place and suggesting guidelines for sustainable development.

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1. Introduction

Every individual who is dependent on the earth's resources for their livelihood creates an imprint on the earth's ecosystem. Our world with its limited resources is hanging by a thread and there is need to protect it. But if we are to conserve our resources, first we need to measure the impact we have on the earth. Carrying Capacity Network defines carrying capacity as the number of individuals who can be supported in a given area within natural resource

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limits and without degrading the natural, social, cultural and economic environment for present and future generations [1]. Carrying capacity is a tool to measure the human impact on the earth.

1.1. Need for the study

If we consider the development pattern of Kerala, we can observe a rapid shift of rural population to urban areas. Also the high population density of Kerala which is about 859 pp.sq.km [2] and especially the high population density of urban areas of Ernakulam reflect on the rapid development of the region.The rapid rate of urbanisation and development leads to detrimental effects like pollution, depletion of resources, dense urban development, lack of open spaces, etc. over time [3]. At present there is no tool available in Kerala to operationalize carrying capacity.

2. Background Studies

2.1. Carrying capacity of a place

"Carrying capacity is not just a scientific concept or formula of obtaining a number beyond which development should cease, but a process where the eventual limits must be considered as guidance. They should be carefully assessed and monitored, complemented with other standards, etc. Carrying capacity is not fixed." [4] The concept of carrying capacity was developed by Thomas Malthus in 1798 and he concluded that there is a distinct amount of human beings the earth can sustain for a definite time. Socio-economic status of the people of an area and the use of technology are the two major factors that manipulate the carrying capacity of that area [5].

2.2. Ecological footprint analysis

According to Global Footprint Network, ecological footprint represents the productive area required to provide the renewable resources humanity is using and to absorb its waste. Ecological Footprint Analysis (EFA) is a tool developed by William Rees and M. Wackernagel which represents the ecological load imposed on the earth by humans in spatial terms. According to Dr. Mathis Wackernagel, there are two basic approaches for calculating ecological footprint: compound based approach and component based approach[8].

Sustainability is indicated by ecological quotient (EQ) which is the ratio of total ecological footprint and the share of supply limits of nature. [9]
EQ <1 is sustainable
EQ >1 is unsustainable

2.3. Ecological footprint and carrying capacity

Ecological footprint is closely related to carrying capacity. Ecological Footprint is expressed in ha/capita, while the ecological carrying capacity is usually expressed in units/ha. Hence EF can be said to be an inverse of carrying capacity.Land carrying capacity explains whether the local land resources are effectively used to support economic activities and human population. It can be evaluated by ecological footprint analysis. EFA explains the relationship between the residents and the land resources [10].Hence EFA is known as an effective tool for measuring the sustainable use of natural resources and a land's ability to support human beings; [10] therefore it can be used to assess the land carrying capacity of an area.

3. Review of Case Study

3.1. Ecological footprint analysis of Kochi

The following study was done by Athira Ravi as part of her M.Planning Thesis study. The study focuses on calculating ecological footprint of a few selected wards in Kochi and analysing it on the basis of various factors and components.

- The ecological footprint of Kochi city was calculated using the global footprint calculator developed by Redefining Progress and Earth Day Network [9].
- Components for footprint calculation were food, mobility choices, shelter and goods and services[9].
- For the purpose of primary studies random samples of the residential areas in the city were selected. The criteria for selection were
    - Density of population
    - Concentration of high rise buildings
    - Location [9]
- The average footprint of residents in the city area is above the national average. (2.19 > 0.8) [9]
- According to the Global footprint calculator if everyone lived like this we would need 1.3 PLANETS to sustain our life [9].

Table 1. Comparison of category wise ecological footprints of selected wards

Ward No	Ward Name	Population	Number of Household	Food Footprint	Shelter Footprint	Goods and Services Footprint	Mobility Footprint	Total footprint
7	Pandikudy	7741	2012	0.45	1.03	0.61	0.2	2.29
50	Panampilly Nagar	8024	2143	0.36	1.15	0.65	0.21	2.37
20	Mundamveli	8747	2010	0.39	1.02	0.59	0.3	2.3
58	Ernakulam North	9973	2738	0.35	1.21	0.70	0.26	2.52
31	Ponnekara	9025	2296	0.37	0.85	0.46	0.23	1.91
53	Thevara	5119	1467	0.4	0.78	0.42	0.19	1.79

3.2. Ecological footprint analysis of Vancouver

Metro Vancouver has a population of approximately 2.1 million people and has a total area of 283,187 ha. It comprises of 22 municipalities [11]. Business services, tourism, agriculture and manufacturing are the main economic activities [11].

Table 2: Comparison of material and energy input of components of ecological footprint

	Water	Consumables and waste	Transportation	Buildings	Food
Total Material Input	424,860,000 m^3	2,399,900 tonnes	3,338,721,000 litres	-	1,753,000 tonnes
Per capita Material Input	202.31 m^3	1.14 tonnes	1,589.86 litres	-	0.83 tonnes
Total Energy Input (MWh)	107,275	29,000	146,525	17,515,150	-
Per capita Energy Input (MWh)	0.05	0.01	0.07	8.34	-

Table 3: Comparison of outputs of components of ecological footprint

	Water	Consumables and waste	Transportation	Buildings	Food
Total Carbon emission (tonnes)	87,106	3,455,000	9,337,930	6,440,600	3,482,100
Per capita carbon Emission (Tonnes)	0.04	1.64	4.45	3.07	1.66
Total waste generated (tonnes)	462,053,500	1,139,560	-	325,600	392,470
Per capita waste generated (tonnes)	220.03	0.54	-	0.16	0.19

Table 4: Comparison of Components of Ecological Footprint of Metro Vancouver

Components	Food Footprint	Shelter footprint	Goods and Services Footprint	Mobility Footprint	Water Footprint	Total Footprint
Ecological footprint (GHa)	4,514,400	1,779,220	1,420,300	2,323,200	34,550	10,054,400
Per Capita Ecological Footprint (Gha)	2.149	0.847	0.676	1.106	0.016	4.787

3.3. Inferences

The factors affecting the ecological footprints of Cochin and Vancouver were carefully studied. There are 4 components which affect the footprint of an area namely, food, shelter, goods and services and mobility. Architectural and urban design interventions cannot be made to affect all of these categories. The possible areas for urban design and architectural intervention in order to reduce the overall footprint thereby optimising the carrying capacity area:

- Housing
- Transportation
- Services and Infrastructure

In order to reduce mobility footprint,

- Promote public transportation
- Use energy efficient vehicles
- Mixed landuse will also reduce the dependency on private vehicle for transportation and promote use of public transportation and walking.

In order to reduce shelter footprint,

- Reduce energy demand for housing.
- The land area consumption can be reduced by increasing density of residential living in order to promote apartment style development.
- Apply building regulation on house area usage and occupancy rate.

In order to reduce the goods and services footprint,

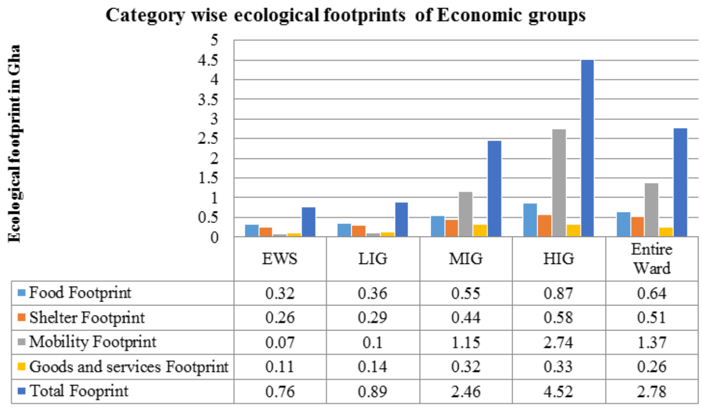
- Purchase goods that are locally manufactured which would reduce the material and energy input for manufacture of the product.
- Restrict use of disposable items.
- Reduce use of various products and production of waste
- Reuse and recycle waste

4. Primary study

The area selected for the purpose of study is Vyttila Ward (Ward no.48) in Kanayannur Taluk, Ernakulam District in Kerala. The study area is defined by NH-47 in the East, backwaters in the west and South and S.A road in the North. It has an area of 0.92 sq.km and a total population of 9126. There are a total number of 2415 households.

4.1. Ecological footprint analysis of study area

The method used for ecological footprint analysis is adopted from the study by Athira Ravi on Ecological Footprint Analysis of Cochin city.



	EWS	LIG	MIG	HIG	Entire Ward
Food Footprint	0.32	0.36	0.55	0.87	0.64
Shelter Footprint	0.26	0.29	0.44	0.58	0.51
Mobility Footprint	0.07	0.1	1.15	2.74	1.37
Goods and services Footprint	0.11	0.14	0.32	0.33	0.26
Total Fooprint	0.76	0.89	2.46	4.52	2.78

Fig.1.Graph Showing Ecological Footprint of various Economic Groups.

- The average footprint of residents in the study area is 2 GHa which is above the national average of 0.08 GHa.
- Hence, if everyone continued to live in this manner, we would require 1.2 planets to sustain the population.

Table 5: Comparison of occupancy rate and electricity consumption with shelter footprint

	EWS	LIG	MIG	HIG	Entire ward
Occupancy rate (sq.ft per person)	42.75	133	285	660.75	425
Electricity consumption (kWhr)	0.8	1.25	2.4	4	2.8
Shelter Footprint (gha)	0.26	0.29	0.44	0.58	0.51
Ecological Footprint (gha)	0.76	0.89	2.46	4.52	2.78

- From the above table, it is evident that occupancy rate is directly proportional to the shelter footprint.
- Electricity consumption in households contributes to the shelter footprint. Footprint can be reduced by using alternative renewable sources of energy like solar energy.

Table 6: Comparison of water consumption and dry waste generation with goods and services footprint

	EWS	LIG	MIG	HIG	Entire ward
Water consumption (lpcd)	95.25	98.25	115.75	139	128

Dry waste generated (grams)	180	200	200	245	215
Goods and services footprint (gha)	0.11	0.14	0.32	0.33	0.26
Ecological Footprint (gha)	0.76	0.89	2.46	4.52	2.78

- The amount of water consumed affects the goods and services footprint. Strategies for water consumption by reducing, reusing and recycling water can reduce the total footprint.
- Goods and services footprint is influenced by the waste output of various consumables. This can be reduced by avoiding use of unnecessary goods, reusing and recycling it.
- Shelter footprint for one storied, two storied and three storied residences with comparable floor area showed to decrease the shelter footprint while increasing the building height
- Scenario A:
  When average per capita house area usage is 485 sq.ft and a renewable source of energy is used to meet energy requirements. This will reduce shelter footprint. In order to reduce mobility footprint, the use of public transportation need to be encouraged, the distance between the origin and destination is to be reduced.

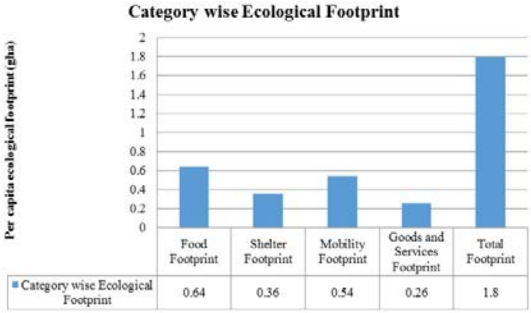


Fig.2.Component wise ecological footprint by applying scenario A

By applying the above conditions, shelter footprint is reduced from 051 to 0.36 gha and mobility footprint is reduced 1.37 to 0.54 gha.

- Scenario B:
  When shelter footprint is reduced by giving average per capita house area usage as 350 sq.ft and a renewable source of energy is used to meet energy requirements. In order to reduce mobility footprint, fuel efficient vehicles are used and the distance between the origin and destination is is reduced.

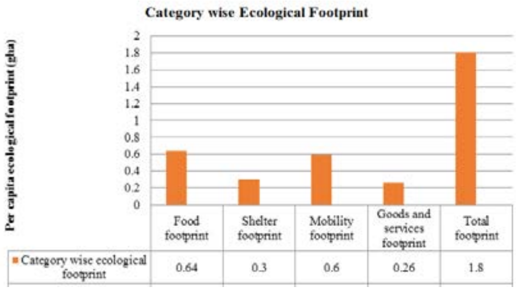


Fig.3.Component wise ecological footprint by applying scenario B

Shelter footprint is reduced by 0.17 gha and mobility footprint by 0.77 gha.

5. Urban design guidelines for optimum carrying capacity

Based on the study, guidelines derived to achieve optimum carrying capacity are:

Housing

- Density and footprint
  - Redensification of households within the study area is required as there is a huge disparity in distribution of households within the ward.
  - The shelter footprint of apartments is 0.21 gha, that for individual row housing units is 0.568 gha and shelter footprint for individual units is 0.77-1.21 gha [9]. For the same number of housing units, apartments tend to consume less land resources which in turn reduce the shelter footprint.
  - According to scenario A, the permissible shelter footprint in order to achieve optimum carrying capacity is 0.36 gha. This can be achieved by a number of combinations of apartments, row houses and individual units.
  - Also shelter footprint of multi storied houses is less than that of single storied houses with comparable floor area. Multi storied residences are preferred.
- Building Regulations and FAR
  - Based on study, average per capita house area usage was estimated to be 485 sq.ft. From this, optimum area of a house with a household size of 4 is estimated to be 1940 sq.ft.
  - For small plots, i.e. plots of area 3 cents (125m2) or less, the optimum FAR is 1.45.
  - For plots of area 10 cents (420 m2), the optimum FAR is 0.45 and coverage is 25%.
- Material and Technology
  - Use of energy efficient materials and renewable sources of energy reduces the shelter footprint by 0.11 gha. Renewable sources of energy include wind energy, solar energy, biomass, tidal energy etc.
  - Usage of materials with low embodied energy tends to reduce the overall shelter footprint.
  - Concrete, bricks, clay tiles have low embodied energy. Ceramic tiles, plywood, timber have relatively low embodied energy as well. Recycled construction materials also have very low embodied energy. Locally produced materials are to be utilised in order to reduce the shelter footprint.
- Sustainable Building Technology and Methods

Energy efficient technology for manufacturing of building materials, construction and operation of buildings reduce ecological footprint from 0.51 to 0.4 gha. Most methods currently used for increasing building energy efficiency are focused on minimizing unwanted solar heat gain, maximizing usable natural light and heat, and minimizing building heat loss through air leaks around windows and ductwork [12]. Some of those methods are:

- Passive Solar Design Techniques
- Thermal storage:
- Cooling strategies
- Daylighting
- High performance insulation etc.[12].

Transportation

- To achieve optimum carrying capacity, mobility footprint can be reduced to 0.6 from 1.37 gha. This can be done by increasing dependence on public transportation, use of fuel efficient vehicles, encouraging pedestrianisation and reducing distance between place of origin and destination.

- Mixed use development is preferred which would reduce the distance between places of origin and destination.
- An efficient system of public transportation linking remote areas as well with multi modal transportation hubs in city centres where modes of transportation can be interchanged.
- Improve pedestrian facilities and increase open areas to encourage walking and cycling.

Services- Solid waste, electricity, water supply, sewage and drainage

- Reduction of waste: This is to be done at the households itself. Households can be charged on the basis of waste generated and frequency of collection of waste.
- Promote recycling of waste and encourage use of recycled products
- Waste disposal and treatment at individual households- implement installation of household or community biogas plants and composting pits at cheap rates or with subsidy.
- Construction wastes can be recycled
- Encourage use of energy efficient appliances and implement passive design strategies to reduce consumption of electricity.

6. Conclusion

The study area has been carefully evaluated on the basis of its carrying capacity. Carrying capacity is an effective tool in assessing an urban area. Although various sustainability guidelines have been suggested, detailed studies regarding this is required to develop these guidelines. The study is merely a base for initiating steps for optimising resource consumption and waste generation of urban areas by highlighting the existing scenario.

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